UTAH GEOLOGICAL SURVEY

SURVEY NOTES

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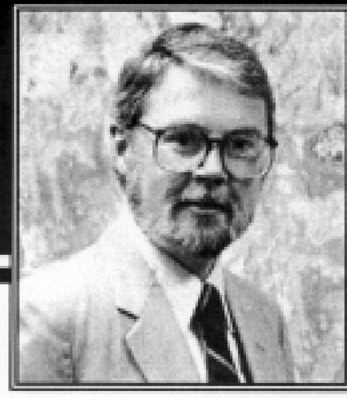


The Director's Perspective

by M. Lee Allison

For many years geologists in Utah were perplexed as to why the State Paleontologist was housed in the Division of State History (DSH) rather than in the Utah Geological Survey. That question was also asked in the UGS and DSH as well as by a special Antiquities Tast Force convened by DSH. So for the past year the two state agencies have negotiated a transfer of personnel. I am pleased to report that effective October 8, 1994, the UGS added a team of scientists to our staff.

Dr. David Gillette, Utah State Paleontologist, continues to serve in that position at the UGS. Dr. David Madsen, a paleontologist and previously Utah State Archeologist, left that title with DSH, but brought his considerable expertise and experience to the UGS where he is manager of the new tentatively named Paleontology section. Martha Hayden is continuing to provide technical and logistical assistance to the pair. A number of part-time and contract staff will also come to the UGS to work on specific outside-funded projects.

We are excited too, about creating new ties to the Utah Friends of Paleontology, a volunteer group that participates in archeological and paleontological excavations and other activities. This energetic and enthusiastic group donates thousands of hours of labor every year towards the better understanding of our natural heritage.

DSH retains the archeology permitting function for the state but will have better defined mission and streamlined structure as a result of the transfer. The UGS gains a team of researchers that has international credentials and acclaim. Dr. Madsen will be heading up a cooperative project with the Chinese next year in central Asia funded by the National Science Foundation and the National Geographic Society. Dr. Gillette, whose new book on seismosaurus is a best-seller, will be on a nation-wide tour as a Distinguished Lecturer for the American Association of Petroleum Geologists. Both will continue to work on a variety of Utah projects and provide assistance to local governments. They will also be developing new projects at the UGS on their own and in conjunction with other UGS staff. The UGS will assume the responsibility for issuing paleontological permits on state sovereign lands - navigable lake and river bottoms deeded to Utah at the time of statehood. Historically, only about four such permits per year have been issued.

In another exciting development, the UGS is providing scientific support to a new 5-year project to characterize slope-basin and turbidite sediments for enhanced oil recovery in cooperation with ARCO Western Energy of California. This $5.8 million project is headed by the Earth Sciences and Resources Institute at the University of Utah. The U.S. Department of Energy and ARCO are funding it. This is the fourth industry-government petroleum partnership the UGS has received funding for in the past two years.

This addition to the UGS staff and the new cooperative project adds to our growing reputation as a regional, national, and soon to be international, research center in the applied earth sciences. They give the UGS greater ability and resources to meet the growing needs of Utah's citizens.

Survey Notes is published three times yearly by Utah Geological Survey, 2363 South Foothill Drive, Salt Lake City, Utah 84109-1491; (801) 467-7970. The UGS inventories the geologic resources of the state, identifies its geologic hazards, disseminates information concerning Utah's geology, and advises policymakers on geologic issues. The UGS is a division of the Department of Natural Resources. Single copies of *Survey Notes* are distributed free of charge to residents within the United States and Canada. Reproduction is encouraged with recognition of source.

Geologic-hazards mapping by the Utah Geological Survey

by Gary E. Christenson

The Utah Geological Survey (UGS) maintains an active program of geologic-hazards mapping throughout the state. This program provides information to developers, geologists, engineers, and state and local government planners and regulators to help protect Utah's citizens and reduce property losses from geologic hazards. Geologic hazards considered in the program include earthquakes, landslides, radon, problem soil and rock, shallow ground water, and flooding.

A challenge frequently encountered in supplying geologic-hazards information is to educate potential users and assist them in applying the information. To aid in this process the UGS provides "translated" products, mostly interpreted maps and explanatory reports, that present information which may be readily used and understood by non-geologists. In addition, the UGS provides "follow-up" services such as assistance to local governments in developing hazards ordinances, discussions with developers and consultants involving requirements for geologic reports, reviews of geologic reports, and presentations to professional, government, and citizen groups.

The principal products of the UGS geologic-hazards mapping program are: (1) a computerized geologic-hazards bibliography, (2) state hazards maps (1:500,000 to 1:1,000,000 scale), and (3) city and county hazards maps (1:24,000 or larger scale).

Flood and debris flow in Covered Bridge Canyon, Utah County, during the spring of 1983.

Computerized geologic-hazards bibliography

The geologic-hazards bibliography is a comprehensive listing of published and unpublished information and maps which specifically address geologic hazards in the state. References include scientific studies, site-specific consultant's geotechnical reports, regional hazards compilations, and government documents. The bibliography is of value to practicing scientists and engineers for background literature searches as well as to non-technical users interested in knowing what information is available for their particular area and need. Each reference is assigned key words which identify the hazards discussed, types of information included, and geographic area covered (county, 7½-minute quadrangle).

The bibliography is available on disk (Harty and others, 1992) and can be used in various database-management programs to apply the key-word search capability. Computer searches can be performed at the UGS on a public-access computer, and hard-copy printouts of key-word, author, and title searches are also available.

State hazards maps

Using the database compiled for the geologic-hazards bibliography, statewide geologic-hazards maps have been produced. Maps depict:

(1) shallow ground water and related hazards (Hecker and others, 1988),

(2) flood hazard from lakes and failure of dams (Harty and Christenson, 1988),

(3) landslides (Harty, 1991; also available for each 30 X 60-minute quadrangle at a scale of 1:100,000),

(4) soil and rock causing engineering-geologic problems (Mulvey, 1992b),

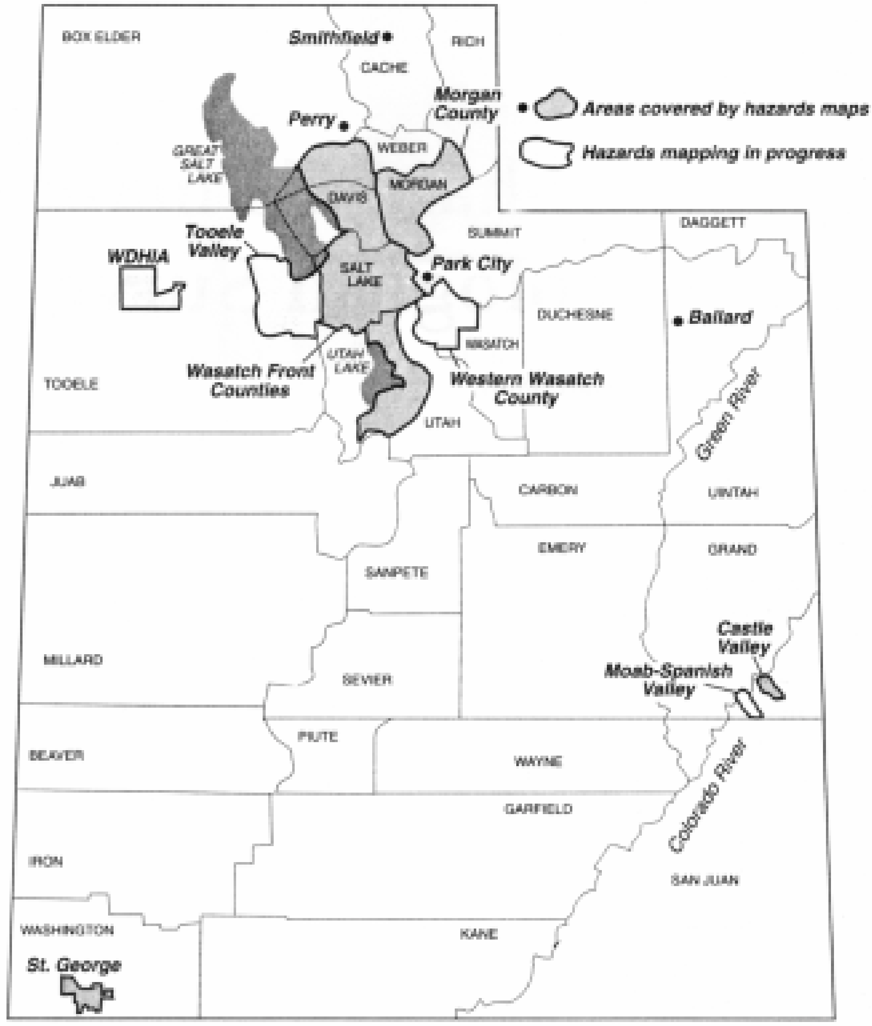
(5) Quaternary tectonics (Hecker, 1993),

(6) radon-hazard potential (Sprinkel and Solomon, 1990; Black, 1993), and

(7) earthquake hazards (Christenson, in preparation).

These maps vary from "occurrence" maps such as the landslide map which shows existing landslides, to hazard-potential maps such as the radon map which shows the relative potential for high indoor-radon levels.

Each state hazards map includes a text explaining how the map was compiled and how best to use it in planning. The maps vary in scale from 1:500,000 to 1:1,000,000, and give a regional overview of the extent of the hazard and its relative importance statewide. The maps are not well suited for use in city or county hazards ordinances except as preliminary guides to potential hazards in areas where more detailed maps (see below) are not yet available. These state hazards maps can be purchased at the UGS and will soon be available in digital form or hard copy (map only) in the State Geographic Information Database (SGID) from the Utah Automated Geographic Reference Center (AGRC; Division of Information Technology Services, Utah Department of Administrative Services).



Areas where geologic-hazards maps (1:24,000 or larger scale) are complete or in progress (WDHIA — West Desert Hazardous Industries Area).

City and county hazards maps

In Utah, local governments (cities, towns, and counties) have authority for land-use regulation. To exercise their authority to protect life and property from geologic hazards, local governments need hazards maps at a scale their planners and engineers can use in regulating development. This generally requires maps at a scale of 1:24,000 or larger. The UGS has undertaken such mapping, or sponsored projects to prepare such maps, in many urban areas of the state, concentrating along the Wasatch Front (see figure).

Through the UGS-sponsored Wasatch Front County Geologist Program, mapping for Salt Lake and Davis Counties and parts of Weber and Utah Counties has been completed (see figure). These maps are available through each county planning department. The maps are also being added to the SGID by AGRC.

The UGS has prepared multihazard maps and reports for Morgan County (Kaliser, 1972), Perry (Lund, 1981), Ballard (Christenson, 1981), the St. George area (Christenson and Deen, 1983), Smithfield (Christenson, 1983), Park City (Gill and Lund, 1984), and Castle Valley (Mulvey, 1992a) (see figure). Geologic-hazards mapping is presently underway and scheduled for completion in the next year or so in Moab-Spanish Valley, western Wasatch County (Heber Valley), and parts of Tooele County (Tooele Valley and the West Desert Hazardous Industry Area [WDHIA]) (see figure). The article in this issue of Survey Notes by B.J. Solomon, K.M. Harty, and B.D. Black on the Tooele County project describes the type of information provided by these studies and how it is best used.

Maps depicting a specific hazard in a local area are also available (not shown in figure). Kaliser (1977) produced a collapsible soil map of the Cedar City area (now out of print). Everitt and Kaliser (1980) completed seismic-hazards studies for Tooele and Rush Valleys in Tooele County. Radon-hazard-potential maps have been completed or are underway for east Sandy and east Provo (Solomon and others, 1994), the St. George area, Ogden Valley, the central Sevier Valley (Salina to Monroe), western Weber Valley (Roy, Ogden, and Layton areas), Tooele Valley, and southern Cache Valley.

Other hazards maps

The UGS includes discussions of geologic hazards in our 7½-minute (1:24,000-scale) geologic-quadrangle maps and includes geologic-hazards maps (usually 1:100,000 scale) and texts in the county geologic-map series, starting with the Kane County report (Doelling and Davis, 1989). Of course, there are many products other than those produced or sponsored by the UGS that are available in Utah. Federal agencies, Utah universities, and private consultants have produced many valuable hazards maps. Many of these can be identified by consulting the UGS geologic-hazards bibliography.

Future hazards-mapping projects

With the bibliography and state hazards maps nearly complete, the long-term goals of the UGS geologic-hazards mapping program are to keep the bibliography current and complete city and county maps at scales of 1:24,000 or larger for urban areas of the state. Mapping priorities are determined by the population and facilities at risk, extent and severity of hazards, expected urban growth or other development, interest shown by local government officials, and available funding. Cities and counties interested in such mapping should contact the UGS Applied Geology Program to request priority.

Landslide scarps deform gravel road in the Balanced Rock Hills Subdivision in Springdale. The landslide was triggered by the September 2, 1992 St. George Earthquake. (photo by UGS staff)

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Pleistocene bison found in Lake Bonneville sediments

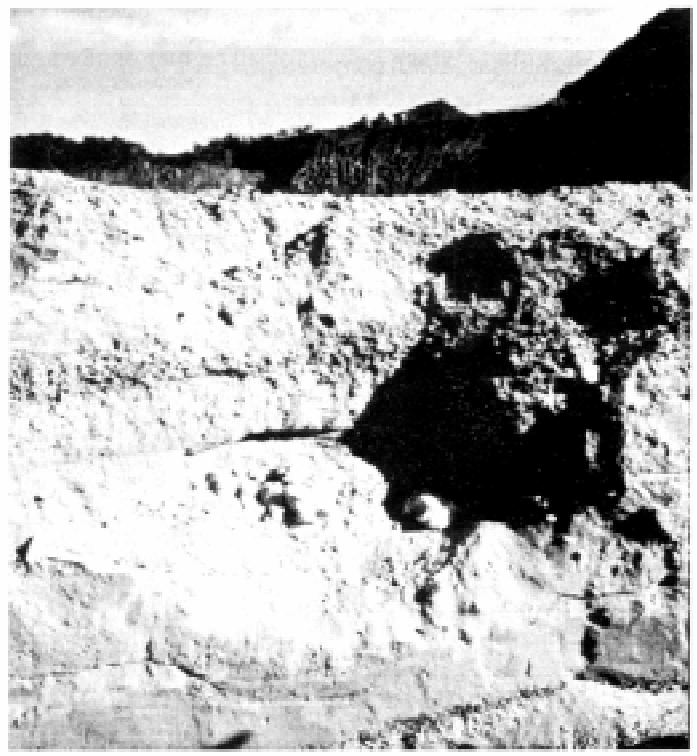
by Rebecca L. Hylland

The Pleistocene Epoch began 1.6 million years ago and ended approximately 10,000 years ago. During the the latter part of the Pleistocene the climate was cooler, allowing grasslands to thrive in Utah, which provided graze for herds of bison, musk oxen, mammoths, and camels. Between about 32,000 and 10,000 years ago a large lake, called Lake Bonneville, covered western Utah and part of eastern Nevada. Conifer forests and grassy meadows covered the mountain slopes that surrounded Lake Bonneville and glaciers scoured the higher mountain summits.

This was the setting of the Salt Lake valley area approximately 18,000 years ago, when a female bison of the genus- species *Bison antiquus* came to the edge of Lake Bonneville, the freshwater ancestor of Great Salt Lake. The Pleistocene bison was about twice the size of the modern bison (*Bison bison bison*), and may have come to the lake to drink. Weariness from old age or disease, or perhaps a hungry predator such as a saber-toothed tiger, dire wolf, or short-faced bear prevented her from leaving the water's edge. For whatever reason, her body was left at the shoreline.

A storm picked the body up and moved it along the beach, where it was re-deposited with fine gravel. The bison lay on the prehistoric beach for several weeks while wave action and scavengers scattered some of its bones. Clean, fine beach sand covered the body relatively quickly, preserving the skeleton. Rising water levels moved the shoreline of Lake Bonneville up the slopes of the Wasatch Range, submerging the bison. At least 15 feet of lake sand and gravel would eventually bury the bison's remains.

Lake Bonneville reached its highest elevation approximately 16,400 years ago, and remained at its high stand long enough to erode a shoreline (the Bonneville shoreline) into the mountain slopes. The lake began to recede about 15,000 years ago, when it catastrophically breached its threshold at Zenda, Idaho and flowed into the Snake River drainage. From about 14,000 to approximately 8,000 years ago, the climate slowly warmed, drying out



Pleistocene bison exposed in trench.

the land and shrinking Lake Bonneville. During this warming period, several animal species became extinct; *Bison antiquus* disappeared about 11,000 years ago.

In July 1994, thousands of years after its burial, the female bison was uncovered by a back-hoe operator excavating building footings not far downslope from the Bonneville shoreline on the east bench of Salt Lake City. State paleontologists and archaeologists were notified of the find. At the construction site they found a well-preserved, partial skeleton. Several vertebrae, ribs, leg bones, a scapula, and part of a horn core were unearthed. Shortly after the ribs were excavated, they began to crack and curl, indicating the presence of protein in the bones. An analytical dating method, accelerated mass spectrometry, may be used to analyze the protein and determine the age of the skeleton to within one hundred years.

This skeleton was an important find because it is the first bison found in stratigraphic context with Lake Bonneville sediments. It is also one of the more complete bison skeletons discovered in the Salt Lake Valley.

The bison skeleton was unearthed in the excavation for the new Huntsman Chemical headquarters building. An exhibit area is planned for the new building which will likely display the bison and include information on other life that thrived along the shores of Lake Bonneville.

(Above) State Paleontologist David Gillette and volunteer Robin Kolb remove soil from the skeleton.

(Left) Track-mounted excavator delicately removes upper layers of sediment.

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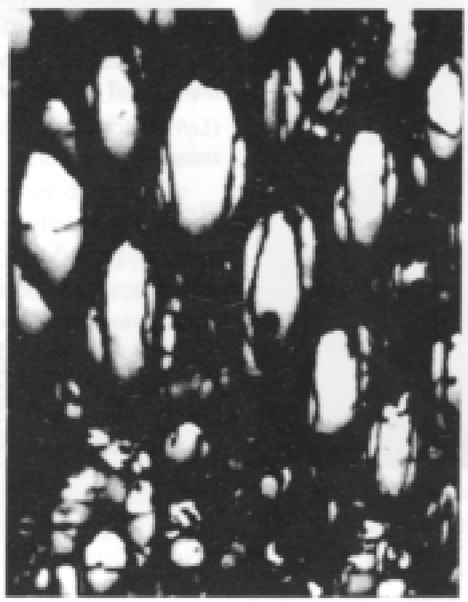
UTAH'S RESINITE:
Resources, History, and Future Recovery

by David Tabet

Resinite is fossilized resin (plant secretions) preserved during coalification. It occurs either as primary, finely disseminated bodies in the coaly matrix, or as secondary, coarse, ovoid bodies or veins filling fractures. This glassy, brittle, amber-colored substance has a low density which permits it to be readily separated from the other woody and mineral-bearing coal fractions using gravity methods. Resinite is used in the black-ink, colored-ink, adhesive, rubber, varnish, coatings, and plastics industries. Research also indicates resinite has potential as a feedstock for special high-density jet fuel. Preliminary sampling by the Utah Geological Survey shows that resinite could be recovered from coal waste piles left by past mining activities, and could help pay for the reclamation of these waste materials.

Resinite forms a very small percentage of almost all coals; however, it is particularly abundant in some Utah coals. Certain coal seams in central Utah's Wasatch Plateau and Book Cliffs coal fields have high resinite contents. Resinite is most abundant in the Hiawatha, Upper Hiawatha, Blind Canyon, Wattis, and the Castlegate group of seams of the Upper Cretaceous Blackhawk Formation. These coal seams average 2.5 to 3.0 percent resinite and locally contain over 10 percent resinite. Central Utah's Blackhawk Formation coal seams contain an estimated 19.4 million short tons (38.8 billion pounds) of recoverable resinite resources.

In the past, gravity-flotation techniques removed only 50 percent of the coal resin. New flotation techniques developed at the University of Utah Department of Metallurgy



Resinite (light-colored) in cell lumens of coal from Utah.

and Metallurgical Engineering by Dr. Jan Miller promise resinite-recovery rates of up to 90 percent. Resinite removal does not significantly affect the quality of the remaining coal, because resinite makes up only a small fraction of the coal, and the process for removing resinite also removes undesirable ash- and sulfur-bearing constituents.

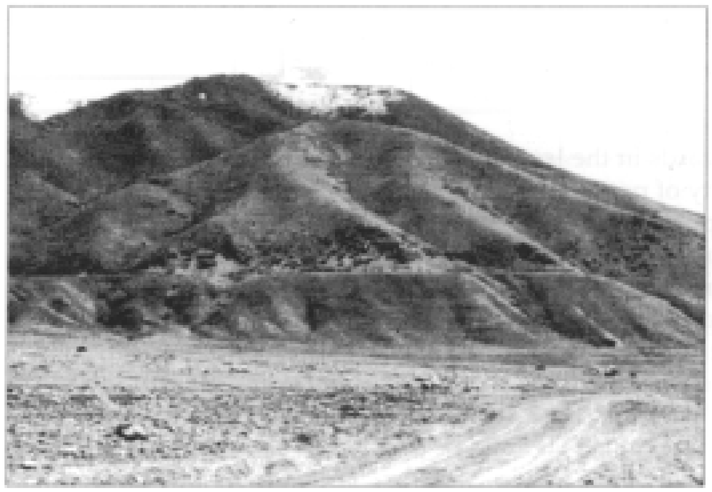
The total annual worldwide consumption of various hydrocarbon resins is about 4.5 billion pounds; however, resinite from Utah has had difficulty gaining a market share due to the lack of coal-resin refiners, and the lack of a reliable supply. Recovery of high-value resinite ($360 to $1,000 per ton) as a coal by-product could markedly increase the revenue to a coal operator.

Utah had an indigenous resin-refining industry from 1947 until 1979, when the solvent extraction plant at Bauer in Tooele County burned down and was not rebuilt. Previous resinite-recovery ventures in Utah have produced between 120,000 and 360,000 pounds of resinite concentrate a year, which may be enough supply to justify construction of a new resin refinery. To restart the coal resin industry in Utah will require a cooperative effort between the resin-supplying mining companies and a resin refiner, so that the miners are assured an outlet for their resin concentrate and that the refiner is assured a large, steady supply of resin feedstock material. Ultimately, re-establishing a Utah resin-refining industry would diversify the Utah industry base, and help the existing coal industry expand into new related markets.

Geologic hazards and land-use planning for Tooele Valley and the West Desert hazardous industry area

by Barry J. Solomon, Kimm M. Harty, and Bill D. Black

Geologic studies have been conducted in Tooele County for more than a century. An 1854 expedition across the Great Basin of the western U.S. inspired E.G. Beckwith (1855) to note the ancient shorelines of "Tuilla Valley" which "will perhaps afford....the means of determining the character of the sea by which they were formed...." Later, the great American geomorphologist G.K. Gilbert (1890) recognized that the landscape of the region had been shaped to a great extent by a large lake, rather than a "sea," and said of the Great Salt Lake Desert that "the area formerly covered by the main body of Lake Bonneville is now a plain, conspicuous for its flatness." He described the "'lost mountains' of Great Salt Lake Desert" as "circled by rocky and inhospitable coasts" during the Lake Bonneville highstand, but the "Cedar Range....bleak and barren as it now is, we may picture as then mantled with verdure" (Gilbert, 1890).

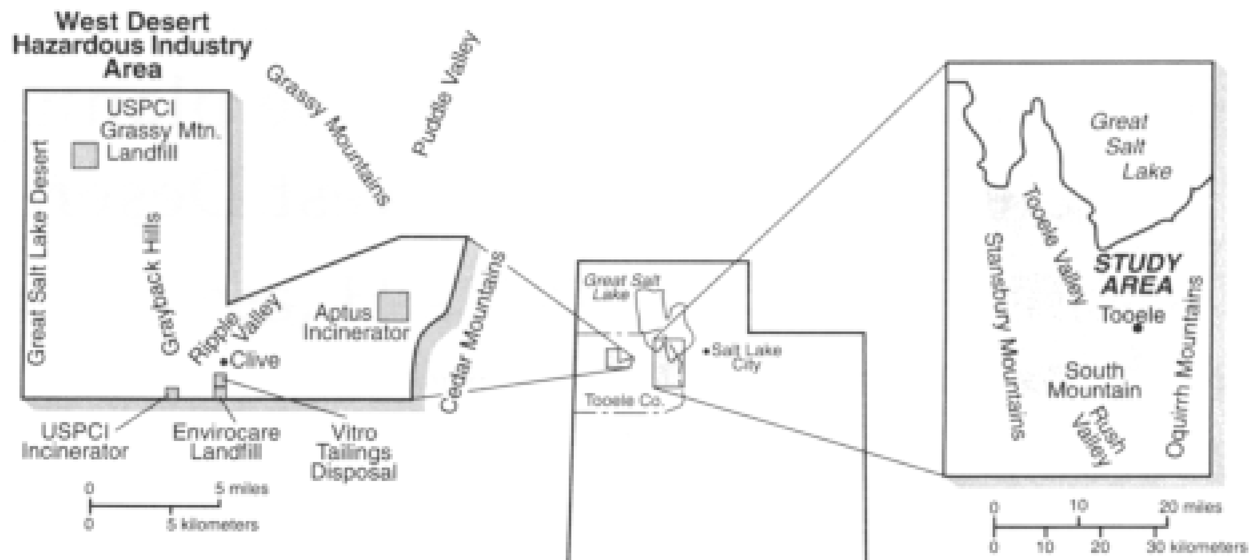


The Bonneville shoreline forms a prominent bench in the foothills of the Oquirrh Mountains near Bates Canyon in northeastern Tooele Valley. Lake Bonneville formed the shoreline between about 16,400 and 15,000 years ago (Oviatt and others, 1992).

The Cedar Mountains, viewed eastward from Ripple Valley, with the light-colored piedmont slope at their base. These are some of the "'lost mountains' of Great Salt Lake Desert" described by Gilbert (1890).

Today, geologic studies determine more than just the nature of ancient processes which formed the landscape. The study of geology provides information to evaluate geologic hazards that must be considered for safe and responsible development. To aid such development, the Utah Geological Survey (UGS) has undertaken a program of geologic-hazards mapping throughout the state (see Christenson, this issue). Two areas were selected in Tooele County for assessment of geologic hazards: (1) Tooele Valley in east-central Tooele County, and (2) the West Desert Hazardous Industry Area (WDHIA) in north-central Tooele County. Tooele Valley contains most of the county's population and is on the western margin of expanding metropolitan Wasatch Front communities. The WDHIA is an administrative unit established by Tooele County to coordinate the development of hazardous-waste treatment, storage, and disposal facilities.

These areas have experienced the ef-



Location map of Tooele Valley and the West Desert Hazardous Industry Area, Tooele County, Utah.

fects of geologic hazards in the last decade, and a variety of potential geologic hazards are present. Above-average precipitation in 1983 and 1984 created some of the more memorable recent geologic hazards, resulting in basement flooding in Erda from shallow ground water, surface flooding in Tooele City from rapid snowmelt and an uncontrolled spill from Settlement Canyon Dam, and landslides and debris flows in canyons in the Oquirrh Mountains on the east side of Tooele Valley. Potential geologic and related environmental hazards include contamination of ground water in basin-fill aquifers; rock falls, debris flows, and flash floods in canyons and along valley margins; and earthquake-related hazards. Adverse foundation-soil conditions are also concerns. Silty and sandy sediments subject to liquefaction or hydrocompaction, clayey sediments and mud flats subject to shrinking or swelling, and gypsiferous dunes and salt flats subject to subsidence due to dissolution are all present in Tooele Valley and the WDHIA. A knowledge of these conditions and related hazard potential will provide decision makers with valuable tools to undertake responsible action.

A report in preparation by the UGS defines the hazards in the selected areas of Tooele County, describes conditions conducive to them, and delineates areas in which each hazard is likely to occur (Solomon, in preparation). Related reports published previously include a preliminary assessment of geologic hazards in the WDHIA (Solomon and Black, 1990), a description of landslides in the Oquirrh Mountains on the eastern margin of Tooele Valley (Harty, 1990), and a road log and summary of geologic hazards in Tooele Valley (Solomon and others, 1992).

The Tooele County report (Solomon, in preparation) will provide a tool for early planning by compiling maps depicting pertinent basic geologic data and constructing derivative maps to delineate areas where adverse geologic conditions might be present. Geologic criteria are important considerations for responsible development.

Setting

Tooele Valley is a rural area in east-central Tooele County. The Oquirrh Mountains form the eastern border of the valley, and the Stansbury Mountains form the western border. Great Salt Lake lies to the north of Tooele Valley, which is separated from Rush Valley to the south by South Mountain. Drainage in Tooele Valley is north into Great Salt Lake. The Tooele Valley study area is bounded by the mountain crest to the west, the county line between Tooele and Salt Lake Counties in the mountains to the east, the lake shore to the north, and includes the northernmost margin of Rush Valley to the south.

Tooele City, in the southeastern corner of Tooele Valley, is about 30 miles (50 km) southwest of Salt Lake City. Tooele City is the county seat and largest community in the county, with a population of 13,887 in 1990; more than 52 percent of the county total. Grantsville, in northwestern Tooele Valley, is the second largest community with an estimated population of 4,500 in 1990 (U.S. Census Bureau, 1990).

Tooele Valley has a semi-arid climate with wide seasonal and diurnal temperature variability (National Oceanic and Atmospheric Administration, 1990). The valley has an approximate mean annual temperature of 50.7° F (10.4° C); mean monthly temperatures are lowest in January (28.8° F [-1.8° C]) and highest in July (75.4° F [24.1° C]). Annual precipitation is 16.5 inches (42.0 cm).

The WDHIA, located in north-central Tooele County, is essentially uninhabited. The Great Salt Lake Desert bounds the WDHIA to the north, west, and south. The Grassy Mountains and Puddle Valley lie to the northeast, and the Cedar Mountains to the southeast. Ripple Valley is in the center of the WDHIA, and is separated from the Great Salt Lake Desert by the Grayback Hills. Drainage of the WDHIA is west into the Great Salt Lake Desert. A zoning district established by the Tooele County Commissioners Board as "Hazardous Industrial District MG-H" defines the perimeter of the WDHIA.

The WDHIA is about 65 miles (105 km) west of Salt Lake City. Four hazardous-waste treatment, storage, and disposal facilities operate in the area and one more is under construction. The first was established by U.S. Pollution Control, Inc. (USPCI) in 1981 when the Grassy Mountain hazardous-waste landfill opened. The site now contains several lined pits for the disposal of hazardous wastes, and equipment for the recycling and chemical destruction of other industrial by-products. The presence of the Grassy Mountain facility provided an incentive for a similar venture at nearby Clive. In 1984, the Utah Department of Health opened a facility at Clive for the disposal of low-level radioactive mill tailings and associated contaminated residues and soil removed from the Vitro uranium mill in South Salt Lake City. The Vitro project, in turn, encouraged Envirocare of Utah to open, in 1988, a landfill for low-level radioactive and mixed (low-level radioactive and hazardous) wastes adjacent to the Clive site. USPCI began operation in 1992 of industrial- and hazardous-waste transfer, storage, and incineration facilities, and similar facilities to be operated by Aptus are under construction. The incinerators are designed to thermally destruct both "hazardous" chemical-waste materials, as defined under the Resource Conservation and Recovery Act, and "toxic" chemical-waste materials, as defined under the Toxic Substance Control Act.

The WDHIA has a more arid climate than Tooele Valley, but both areas have in common the wide seasonal and diurnal temperature variability (National Oceanic and Atmospheric Administration, 1990). The WDHIA has an approximate mean annual temperature of 46.6° F (8.1° C);

Recommended requirements for site-specific investigations for geologic hazards mapped in Solomon (in preparation) (modified from Lowe, 1990, table A-1). Site-specific investigations are also recommended for other geologic hazards described in the study, but not mapped because of insufficient regional information, for all development types.

Hazard	Hazard Area Designation	Development Type			
		Essential facilities, lifelines, special- & high-occupancy buildings	Industrial & commercial buildings (other than high-occupancy)	Residential subdivisions	Residential single lots
Surface fault rupture	In	Yes	No[1]	No[1]	No[1]
	Out	Yes	No	No	No
Liquefaction	High and moderate	Yes	Yes	No[1]	No[1]
	Low and very low	Yes	No	No	No
Landslides	High and Moderate	Yes	Yes	Yes	Yes
	Low and very low	Yes	No	No	No
Debris slides, debris flows, debris floods, and stream floods	In	Yes	Yes[2]	Yes[2]	Yes[2]
	Out	Yes	No	No	No
Rock falls	In	Yes	Yes	Yes	Yes
	Out	Yes	No	No	No
Lake flooding	Below 4,217 ft elevation	Yes	Yes	Yes	Yes
	Above 4,217 ft elevation	No	No	No	No
Ponding and sheet flooding	In	Yes	Yes	Yes	Yes
	Out	Yes	No	No	No
Shallow ground water	0-10 ft	Yes	Yes	Yes	Yes
	10-30 ft	Yes	Yes	Yes	Yes
	30-50 ft	Yes	No	No	No
	>50 ft	Yes	No	No	No
Expansive soil	In	Yes	Yes	Yes	Yes
	Out	Yes	No	No	No
Gypsiferous soil	In	Yes	Yes	Yes	Yes
	Out	Yes	No	No	No

[1] Appropriate disclosure should be required.

[2] If a debris basin is present above the site, a site-specific investigation for debris slides, flows, or floods is not required; the Tooele County Engineering Department should be contacted regarding debris-basin adequacy.

mean monthly temperatures are lowest in January (19.2° F [-7.1° C]) and highest in July (79.0° F [26.1° C]). Annual precipitation is 6.6 inches (16.8 cm).

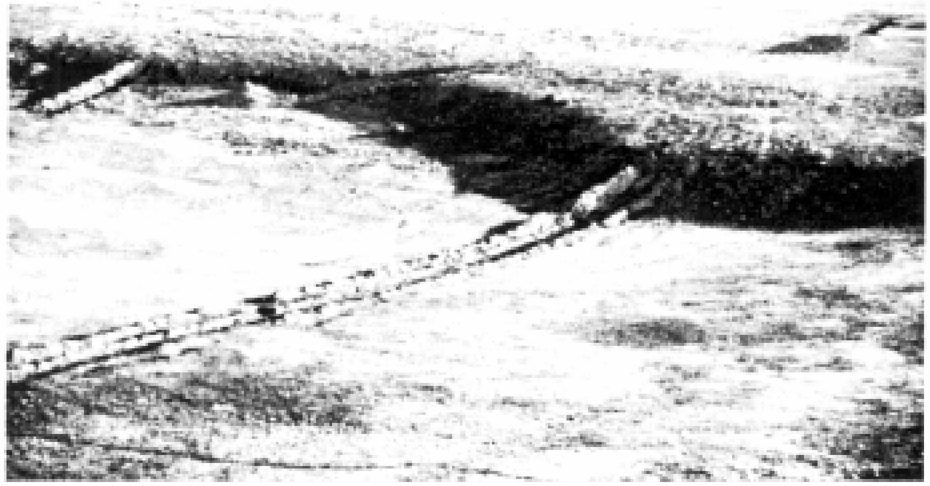
The Study

The Tooele County report (Solomon, in preparation) will consist of a thorough examination of geologic hazards present. A series of maps depicting areas of concern will be constructed for many of the hazards. Surficial geology of the study areas, the basic data from which hazard interpretations will be derived, was mapped at a scale of 1:24,000 (Solomon, 1993). Derivative maps, which delineate areas subject to geologic hazards, will be compiled at the same scale. Mapped hazards include surface fault rupture; liquefaction; rock falls; landslides; debris slides and flows; debris, stream, lake, and sheet floods; ponding; shallow ground water; and expansive and gypsiferous soils. Additional geologic hazards will be discussed in the report for which no hazard maps were prepared because of insufficient information. Unmapped hazards include ground shaking, tectonic subsidence, other earthquake hazards, dam-failure floods, piping, mine subsidence, and indoor radon. All geologic hazards, whether mapped or unmapped, must be considered in site-specific investigations.

Surface Fault Rupture

During a large earthquake, fault rupture at depth may propagate upward and displace the ground surface. This commonly results in the formation of a main fault scarp and adjacent zone of deformation. The zone of deformation, several hundred feet wide along the fault trace, includes features such as ground cracks, tilted blocks, and grabens.

The Oquirrh fault zone (OFZ), present at the eastern margin of Tooele Valley, is the only fault zone in either Tooele Valley or the WDHIA known to have ruptured to the surface during Holocene time (the past 10,000 years) (Barnhard and Dodge, 1988).



A scarp of the Oquirrh fault zone, in shadows just above the middle of the picture, near Big Canyon in northeastern Tooele Valley. The trench was excavated to investigate prehistoric earthquakes along this fault zone (Lund and others, 1994). Photograph by S.S. Olig.

Surface fault rupture occurred along the OFZ during the last 8,000 years (Lund and others, 1994) and a significant potential exists for it to recur. Three smaller faults in the Tooele Valley study area may also have recently ruptured to the surface, but definitive evidence is lacking.

Ground Shaking

Ground shaking is the most widespread and frequent earthquake hazard, and is responsible for most earthquake-related damage (Olig, 1991). Both Tooele Valley and the WDHIA are susceptible to ground shaking both from nearby earthquakes and from more distant earthquakes such as those along the Wasatch fault zone. The Uniform Building Code (UBC) specifies a seismic zonation related to the potential effects of ground shaking (International Conference of Building Officials, 1991). Tooele Valley is in the highest seismic zone in Utah, UBC seismic zone 3; the WDHIA is in both the more moderate zone 2B and zone 3.

Tectonic Subsidence

Tectonic subsidence is the warping, lowering, and tilting of a valley floor that may accompany large surface-faulting earthquakes (about 6.5 mag-

Northern Tooele Valley (flat area, middle ground) is underlain by Lake Bonneville deposits susceptible to liquefaction should earthquake ground shaking of sufficient strength and duration occur. View is west from the Oquirrh Mountains foothills to the Stansbury Mountains.

nitude and greater). This hazard may cause inundation along lake and reservoir shores and ponding of water in areas with shallow ground water. It may adversely affect facilities that require gentle gradients or horizontal floors such as wastewater-treatment plants and sewer lines. Tectonic subsidence may be a hazard in northeastern Tooele Valley associated with surface faulting on the OFZ, but is unlikely to occur in the WDHIA because no surface-faulting hazards have been identified there.

Liquefaction

Liquefaction occurs when earthquake ground shaking causes certain soils to liquefy, lose their ability to support overlying structures, and in some cases move downslope. Northern Tooele Valley and the western WDHIA, where ground-water conditions and soil properties are conducive to liquefaction, are most susceptible. Mabey and Youd (1989) show a significant potential for liquefaction-induced ground failure sufficient to cause moderate to severe damage in areas of high susceptibility in Tooele Valley. Because of a lesser earthquake potential, the hazard is substantially lower in the WDHIA.

Other Earthquake Hazards

A variety of other hazards may accompany earthquakes. These include: (1) ground failure due to loss of strength in sensitive clays; (2) subsidence caused by vibrations in granular materials; and (3) flooding caused by seiches (wave oscillations) in Great Salt Lake, surface-drainage disruptions, and increased ground-water discharge. The extent of property damage and loss of life depends on the earthquake characteristics, duration of ground shaking, proximity to the earthquake epicenter, geologic and hydrologic conditions, nature of foundation materials, and building design. Tooele Valley and the WDHIA may be susceptible to these hazards from both local and distant earthquakes.

The light-colored material in the foreground is a debris-flood deposit which formed during the wet years of 1983 and 1984 in Pass Canyon, in the Oquirrh Mountains near east-central Tooele Valley. Associated with the deposit is a natural levee, or embankment, which borders the deposit and confined the debris flood.

Rock Falls

Rock falls originate when erosion and gravity dislodge rocks from slopes. Rock falls commonly occur during storms and snowmelt, and may also be initiated by earthquakes. During a rock fall, dislodged material travels at high velocities and can pose a threat to structures and personal safety. The rock-fall hazard is greatest in the mountains surrounding Tooele Valley, near the base of the Oquirrh and northern Stansbury Mountains in the valley, and in the Grayback Hills of the WDHIA.

Landslides

Landslides are the downslope movements of generally coherent blocks of rock or soil under the force of gravity. They usually result from changing moisture conditions in susceptible rock or soil, but may be induced by earthquakes. Landslides may affect property, buildings, transportation routes, and utility lines, and may also produce flooding from damming of streams.

Only a few landslides exist in the northern Oquirrh Mountains east of Tooele Valley; their scarcity is due to the prevalance of competent rock. The landslide hazard is greatest in the Oquirrh and Stansbury Mountains toward the southern end of the valley, where the slide-prone Manning Canyon Shale of Mississippian and Pennsylvanian age is present in slopes. No landslides have been found within the WDHIA, where there is no significant landslide hazard.

Debris slides, marked by arrows, in Pass Canyon on the margin of Tooele Valley. These scars were formed when material was dislodged and travelled downslope.

Debris Slides, Debris Flows, Debris Floods, and Stream Floods

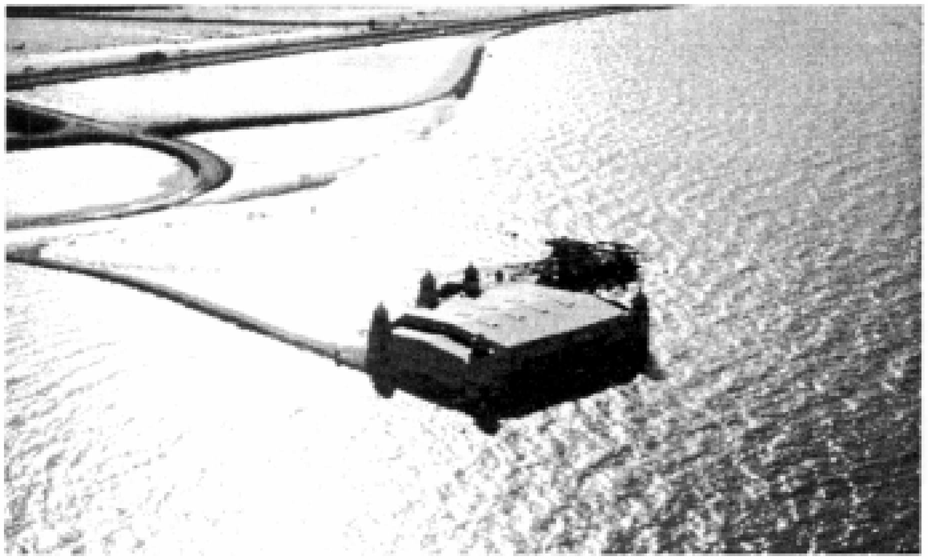
Debris slides, debris flows, debris floods, and stream floods form a continuum of sediment/water mixtures which originate in mountain canyons, but may cause damage over large areas beyond canyon mouths. Loss of life and property damage may result from drowning, high-velocity impact, erosion, or burial.

In Tooele Valley, debris typically originates on canyon slopes in the Oquirrh Mountains near Tooele, which are most susceptible to slope failure; the WDHIA has a low susceptibility. Existing debris-slide, -flow, and -flood deposits are most common in the southern Oquirrh Mountains, where over 90 debris slides and debris flows were identified (Harty, 1990). The greatest hazards are in stream channels and gently sloping areas at channel mouths (alluvial fans) where streams issue from mountain canyons. Such areas include alluvial fans along the Oquirrh and Stansbury Mountain fronts in Tooele Valley; the eastern portion of the WDHIA, which includes extensive alluvial fans deposited by streams from the Cedar Mountains; and small alluvial fans on the margin of the Grayback Hills in the WDHIA.

Dam-Failure Floods

Dam failures generally occur with little or no warning. The severity of resultant flooding depends on the size of the reservoir and the type of failure. The effects of dam-failure floods may include loss of life and structural or other flood damage to buildings. In May of 1983 and 1984, stream inflow exceeded that which could be safely released from the Settlement Canyon Reservoir south of Tooele. Resultant floodwaters inundated Tooele streets, breached a dike, and damaged property (Lund, 1985).

Dam-failure inundation studies are necessary to assess the potential for flooding caused by failure of dams in Tooele Valley (Harty and Christenson, 1988). The WDHIA is not subject to dam-failure flooding because there are no dams in the vicinity.



New Saltair, a recreation facility constructed in 1983 at the northern end of the Oquirrh Mountains, was inundated when Great Salt Lake reached record levels in 1986. Interstate 80 is in the upper part of the picture.

Lake Floods, Sheet Floods, and Ponding

Lake floods inundate low-lying areas during rises in the level of Great Salt Lake. Sheet floods occur when floodwaters, often generated by intense storms, spread over an area and are not concentrated in a well-defined depression or channel. Temporary, localized flooding in low areas during storm runoff or snowmelt is termed ponding. Lake floods may be both seasonal and long term and may produce significant property damage. Sheet floods and ponding are generally seasonal or short-term phenomena, but they may repeatedly occur and can also cause significant local damage.

A lake-flooding hazard may arise in northern Tooele Valley from an increase in the level of Great Salt Lake. Above-average precipitation in the 1980s caused the lake to attain an historical high of 4,211.85 feet (1,283.71 m) in June, 1986 (Arnow and

Mudflats on the western edge of the West Desert Hazardous Industry Area are subject to ponding and sheet flooding during periods of intense rain.

Stephens, 1990) and April, 1987 (U.S. Geological Survey records).

The lake rose to an elevation of 4,217 feet (1285 m) in the 1600s, the record highstand for near recent times, and may reasonably be expected to reach that elevation again in the future (Utah Division of Comprehensive Emergency Management, 1985; Murchison, 1989). Ponding and sheet flooding may occur in the mudflats south of the Great Salt Lake shore in Tooele Valley, and in the mudflats of the Great Salt Lake Desert in the western WDHIA.

Shallow Ground Water

Ground water at depths of less than 30 feet (9 m) poses a hazard to basements, foundations, transportation routes, utility lines, and waste-disposal facilities. Shallow ground water also contributes to the potential for other geologic hazards, including liquefaction, surface flooding, expansive soils, and dissolution of soluble minerals. Shallow ground water is readily polluted by surface sources, and may ultimately contaminate deeper municipal or domestic water supplies.

Shallow ground water is present in northern Tooele Valley, west of the Grayback Hills in the WDHIA, and in northern Ripple Valley in the WDHIA. Shallow ground water flooded basements in Erda in 1985 in response to a sustained pattern of precipitation greater than normal (Lund, 1986).

Problem Soils and Subsidence

Problem soils are surficial geologic materials susceptible to volumetric change, collapse, subsidence, dissolution, or other engineering problems (Mulvey, 1992). In the study areas, mapped problem soils are either expansive or gypsiferous. Unmapped hazards include soils subject to piping and mine subsidence.

Expansive soils are clay-rich, and expand and contract with changes in moisture content. Such soils may crack foundations and road surfaces, and plug wastewater-disposal systems. Expansive soils are widespread in both Tooele Valley and the WDHIA.

Gypsiferous sand dunes on the western edge of the West Desert Hazardous Industry Area. The dunes and material in adjacent mudflats may dissolve and settle, or may form chemical compounds which can adversely react with building foundations.

Gypsum in gypsiferous soils may dissolve, resulting in ground settlement. Gypsiferous soils are also a weak material with low bearing strength, and weather to form sulfuric acid and sulfates which may react with cement and weaken foundations. Gypsiferous soils are found in mudflats of northern Tooele Valley south of the Great Salt Lake shore, and the in Great Salt Lake Desert on the western edge of the WDHIA.

Piping is the subsurface erosion of fine-grained sediment by ground water. This erosion may create large underground voids which could collapse and cause surface subsidence. Fine-grained sediments deposited by Lake Bonneville, present in both the Tooele Valley and WDHIA, are susceptible to piping although there are no documented occurrences.

Subsidence can also be caused by collapse of underground mines. Mine subsidence is a potential hazard on mountain slopes adjacent to Tooele Valley.

Indoor Radon

Radon is a naturally occurring radioactive gas that, when inhaled in sufficient concentrations, can cause lung cancer. High indoor-radon levels are more likely to occur in areas underlain by rock or soil with relatively high amounts of uranium, deep ground water, and high permeability (Solomon and Sprinkel, 1991). Indoor-radon levels also depend on weather, construction type, and occupant lifestyle. A detailed assessment of factors affecting indoor-radon levels is presently being conducted in Tooele County. Regional data suggest that the radon-hazard potential is highest in southeastern Tooele Valley, and lowest in northern Tooele Valley and the Great Salt Lake Desert portion of the WDHIA (Black, 1993).

Recommended use of geologic-hazard maps

The Tooele County geologic-hazard maps (Solomon, in preparation) will be generalized for planning purposes to show areas where site-specific studies are needed. The hazard potential of any specific area may differ from that shown on the maps. Moreover, hazards may exist that are not shown. The maps will, however, provide an indication of hazard potential that a prudent developer should consider prior to construction. Responsible local-government officials should consult the maps early during the planning and permitting process and use them to require the appropriate studies by developers. UGS staff are available to assist local governments in using these maps and reviewing final site-investigation reports.

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The Rockhounder

Wonderstone in the Vernon Hills, Tooele County

By Christine M. Wilkerson

THE ROCKHOUNDER is a regularly appearing column in Survey Notes. In each issue, a member of the Geologic Extension Service will highlight an interesting Utah rock or mineral, and provide information on where and how to collect it.

A striking feature of Vernon Hills wonderstone is its intricately folded bands that create colorful designs in cream, yellow-brown, and multiple shades of maroon.

Geologic information: The Vernon Hills wonderstone is a welded-vitric tuff (vitric means glassy) of rhyolitic composition. It is a volcanic rock composed predominantly of volcanic glass particles which have been welded or stuck together by heat and compacted by the weight of overlying material. Alteration of the rock by circulating ground water produced the colorful banding. The maroon and yellow-brown colors are due to the presence of iron oxides.

How to get there: From the southern edge of Tooele, travel south on State Highway 36 about 31 miles to the town of Vernon. Continue on highway 36 an additional 4 .5 miles until you reach a dirt road adjacent to and west of the railroad tracks. Turn north (left) onto the dirt road and travel next to the railroad tracks for 1.7 miles until the road curves to the northwest. From the curve, travel 0.4 miles to the end of the road.

Each piece of wonderstone in the Vernon Hills has an unique design.

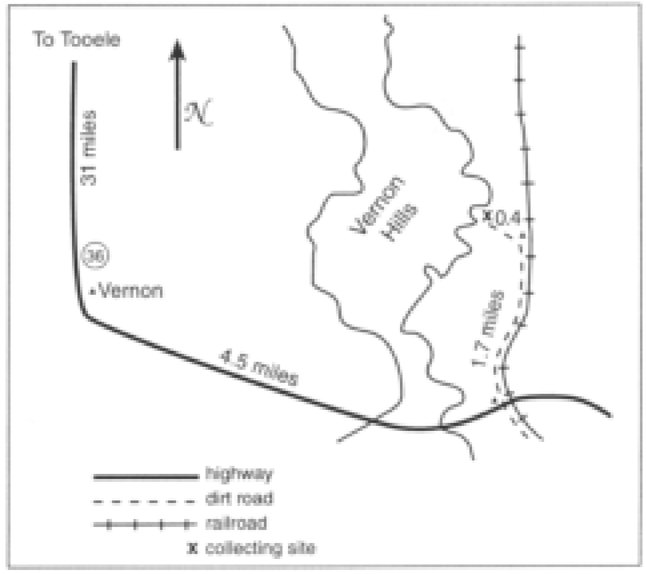
Where to collect: Piles of wonderstone are located near the end of the road. A private mining claim is in this area so do not collect on any marked claims or rock piles showing signs of recent mining activity.

Useful maps: Utah highway map, Rush Valley 1:100,000-scale topographic map, and Lofgreen 7.5-minute topographic map.

Land ownership: Private mining claim and Bureau of Land Management (BLM) public lands.

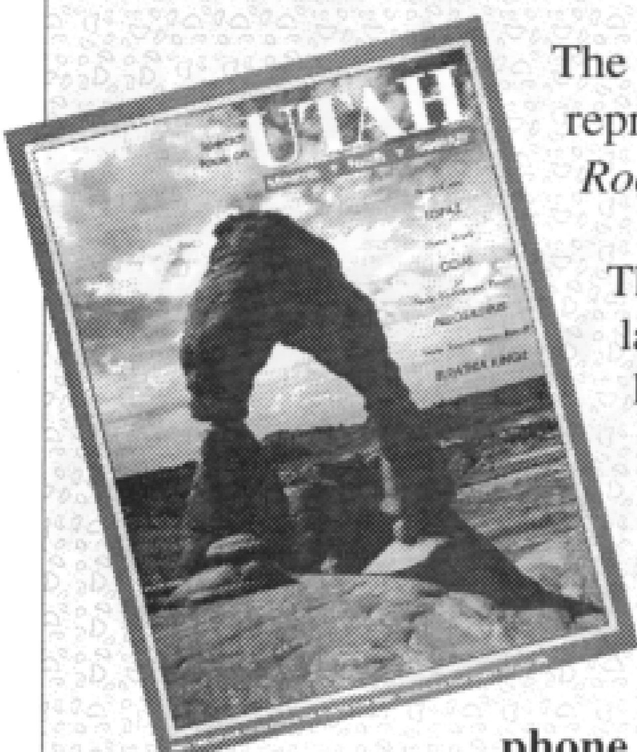
BLM collecting rules: The casual rockhound or collector may take small amounts of petrified wood, fossils, gemstones, and rocks from unrestricted federal lands in Utah without obtaining a special permit if collection is for personal, non-commercial purposes. Collection in large quantities or for commercial purposes requires a permit, lease, or license from the BLM.

Precautions, miscellaneous: A four-wheel-drive vehicle is recommended but not required for the last 2 miles of the journey. Do not collect on any marked claims or rock piles showing signs of recent mining activity. Bring a rock hammer and protective eyewear if you intend to break pieces of rock. A hat and water are recommended. Please carry out your trash. Have fun collecting!



Map of Vernon Hills area showing wonderstone collecting site.

Rockhounds, Collectors, Miners. . .



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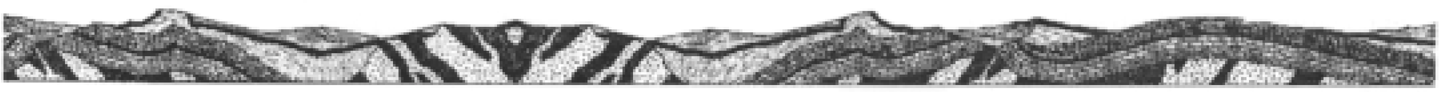
Teacher's Corner

by Sandy Eldredge

Earth's surface - the only constant is change

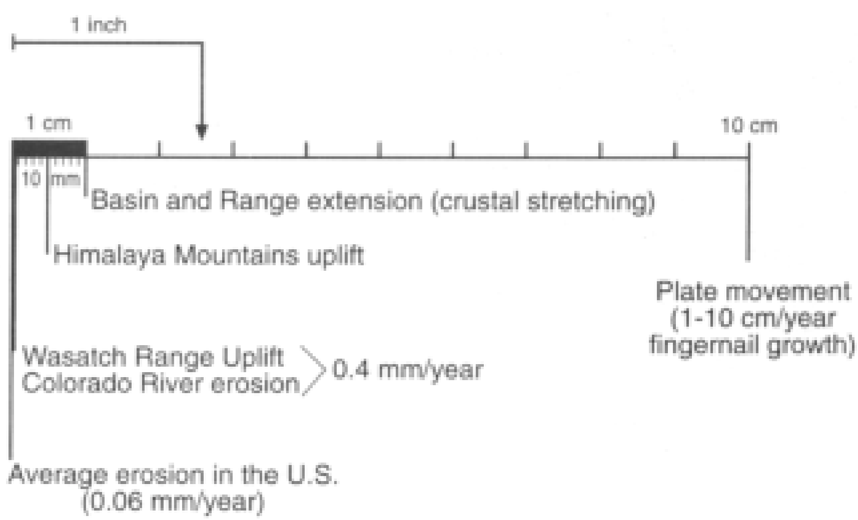


The earth's surface is constantly remodeled by various geological processes. These *changes* are one of the most exciting things about geology - not only are they continuous, but in many cases, observable. Some geological processes, such as those that make mountains or wear them down, typically take place at imperceptible rates. Sudden events, however, can change the landscape in a minute (for example, a single earthquake can create a 3-meter-high fault scarp, alter stream courses, and drop the valley floor 1 meter).

Earth's changes are a topic covered in Utah's new Elementary Science Core Curriculum, in which specific standards and objectives are directed toward increasing knowledge of geological processes and resulting geological features (landforms). Utah is the ideal place for students to observe geology in action. The state contains many types of landforms, such as mountains, plateaus, mesas, river-eroded canyons, glacier-eroded canyons, volcanos, and basins. By observing landforms, students can learn where geological processes, including erosion, mountain building, crustal stretching, earthquakes, geothermal activity, landslides, and rock falls are currently active in Utah.

Rates of these geological processes vary. Below is a comparison of the rates at which some of the slower geological processes transpire. Crustal plate movement, mountain building (except some volcanic mountain building), and erosion are part of the slow evolution of earth's landscape. This evolution is sporadically interrupted by more sudden geological events, such as earthquakes (following the Borah Peak, Idaho earthquake in 1983, the mountain range rose 0.2 meters, and the adjacent valley dropped 1.2 meters), and volcanic activity (in Mexico in 1943, a volcano called Paricutin appeared in a farmer's field and rose 160 meters within a week). Erosion can also happen quite suddenly, and in some cases, may be greatly accelerated by human activities. Flash floods can erode more than 25 centimeters of soil in only a few hours.

Rates (Time/Distance) of Geological Processes in One Year



Energy News

by Thomas C. Chidsey

UGS-Sponsored Core Workshop

The Utah Geological Survey (UGS), Harken Energy Corporation, and the U.S. Department of Energy (DOE) sponsored a core workshop to examine several cores from the Paradox basin of southeastern Utah. The purpose was to determine oil reservoir characteristics of several types of algal mounds (reef-like buildups of porous limestone from ancient growths of algae). The workshop was held during the 1994 American Association of Petroleum Geologists (AAPG) Annual Convention in Denver, Colorado. Thirty-two participants attended the free workshop. This workshop was the first of several planned in the future as part of the technology transfer activities for a major UGS petroleum project funded by the DOE Class II Oil Program - Shallow Shelf Carbonate Reservoirs.

Participants at the UGS-sponsored core workshop, during the AAPG Annual Convention in Denver, examine cores representing various types of oil-producing reservoirs from the Paradox basin of southeastern Utah.

The core workshop was an introductory examination of the relationship between production and reservoir characteristics of algal mounds in the Pennsylvanian (320 million years ago) Paradox Formation. Representative cores from five types of oil-producing algal mounds from the Paradox basin were discussed and examined. Planned activities were described during the workshop for the UGS/DOE project entitled **"Increased Oil Production And Reserves Utilizing Secondary/Tertiary Recovery Techniques On Small Reservoirs In The Paradox Basin, Utah."** Participants were encouraged to question and discuss all aspects of the project and make suggestions or recommendations concerning the project.

As part of the project, the UGS and Harken Energy Corporation will test and evaluate enhanced oil-recovery technologies for a typical oil field in the Paradox basin. A two-phase approach is planned. Phase I will include geological and reservoir characterization of five diverse small fields, evaluation of various secondary/tertiary recovery techniques from reservoir modeling, and identification of the best field for a pilot demonstration. Phase II will be a demonstration project on the selected field using the secondary/tertiary technique identified as having the greatest potential for increased well productivity and ultimate recovery.

New donations to the UGS Sample Library

The UGS Sample Library contains the only publicly available and most complete collection of cuttings, core, and crude oils from oil and gas wells in Utah. It provides a service to petroleum and coal companies as well as to individuals who require direct observation of samples for their research or energy-resource investigations, and it acts as a repository for irreplaceable geologic samples which might otherwise be lost or discarded.

This year the Sample Library has received several significant donations of core and cuttings. Donations were from the Paradox basin, Uinta basin, the southern Green River basin oil and gas fields, and the Book Cliffs coal field.

Paradox basin: For the first, time Harken Energy Corporation (formerly Chuska Energy Company) has released cuttings from their wildcat and development wells on Navajo Nation lands in the southern Paradox basin of San Juan County. Cuttings from approximately 65 wells were donated; to date, 44 of the wells have been catalogued. In addition, the U.S. Geological Survey (USGS) donated 492 feet (150 m) of core from six wells in the basin (San Juan and Grand Counties).

Uinta basin: From the Uinta basin, Balcron Oil donated cuttings from eight wells in the Monument Butte field and the USGS donated 250 feet (76 m) of core from a well in the eastern Bluebell field. Both fields are in Duchesne County. Terra Tek, Inc. donated core (42 feet [13 m]) from a well in the Coyote Basin field, Uintah County.

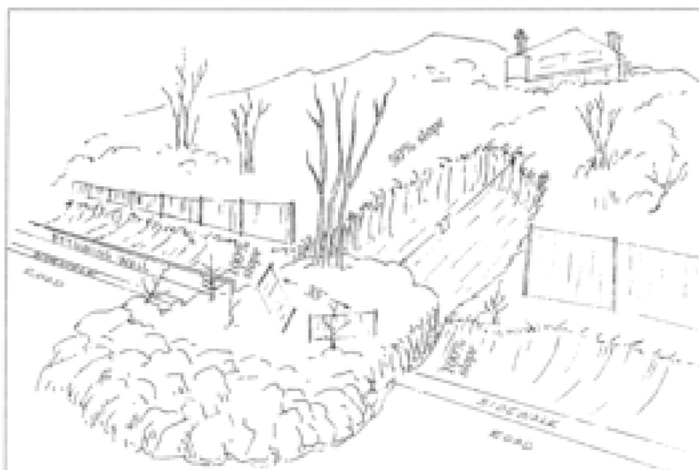
Green River basin: The USGS donated 250 feet (76 m) of core from Clay Basin field, Daggett County, in the southern Green River basin.

Book Cliffs coal field: The Sample Library acquired approximately 4,500 feet (1,370 m) of coal cores from 20 drill holes in the Book Cliffs coal field (Carbon and Emery Counties). The drill holes, completed by the Sunnyside Coal Company, Intermountain Power Agency, and Kaiser Steel Corporation, are scattered over a distance of nearly 30 miles (50 km), from the central to southern Book Cliffs. A complete list of wells and depth intervals of samples is available from the UGS.

Landslide in Olympus Cove, Salt Lake County

by Merrill K. Ridd

University of Utah Research Institute



On April 20, 1994, sometime prior to dawn, a translational landslide occurred in the Olympus Cove area. The slide was on a steep, north-facing slope at the northern food of Mt. Olympus. The general slope at the site is about 50 percent. The slide, about 90 feet long, 35 feet wide, and 4 - 5 feet thick, extended across a sidewalk and onto the road (Thousand Oaks Circle) about 16 feet. The slide was entirely in unconsolidated material with a deep residual soil profile on the Ophir Formation, and predominantly shale parent material.

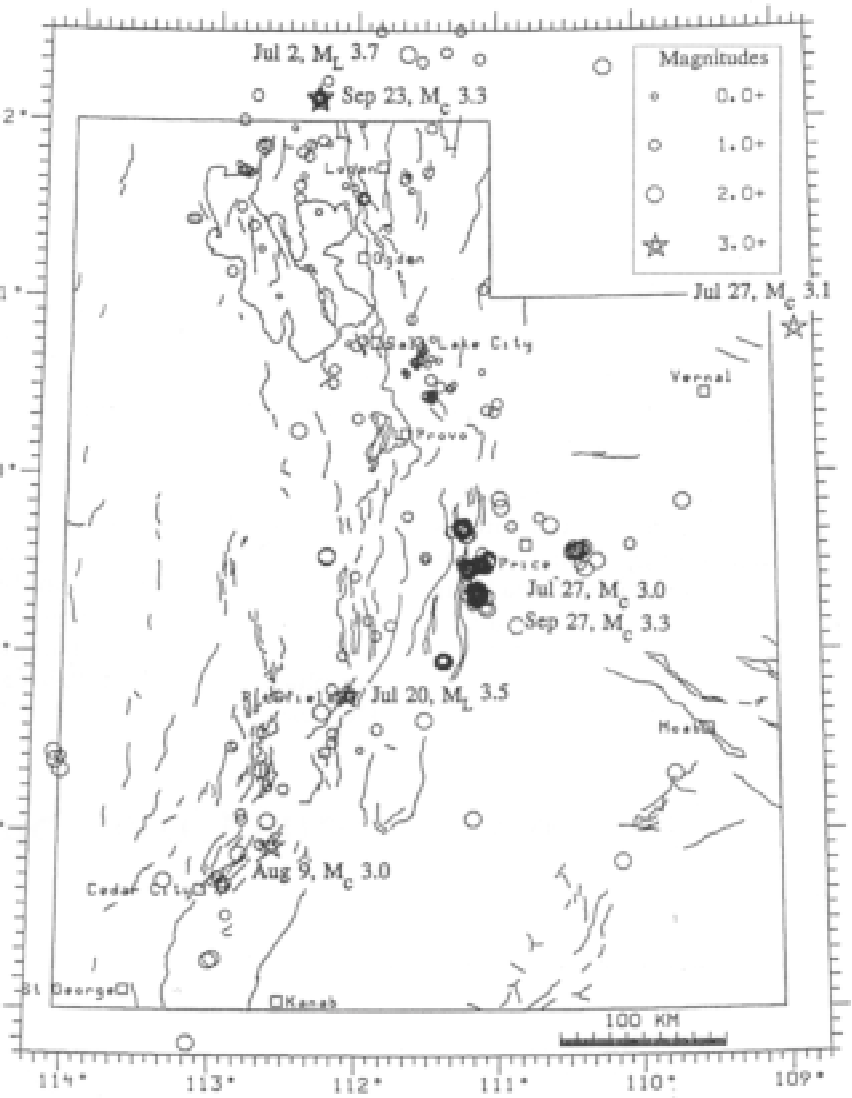
Several factors, both natural and human, gave rise to the slide. The general area is naturally prone to sliding because it is a steep north-facing slope with an abundant supply of natural water through precipitation and snowmelt and soil that is rich in clay. A road cut on the steep slope below the slide increased the slope to over 100 percent on the uphill side of the road. For over 300 feet along the south side of Thousand Oaks Circle the land is moving. Also, additional water from an extensive irrigation system to support trees and shrubs planted on the slope to control erosion probably helped trigger the slide by deeply wetting the clayey soils.

This event is not unique in the Olympus Cove area, where landslides, differential settling, and water-control erosion problems are common. The current concern over slope stability as exemplified by this slide is becoming more critical as development continues on the north foot of Mt. Olympus.

Earthquake activity in the Utah region

by Susan J. Nava
University of Utah Seismograph Stations,
Department of Geology and Geophysics
Salt Lake City, UT 84112-1183
(801) 581-6274

July 1 - September 30, 1993



From July 1 through September 30, 1993, the University of Utah Seismograph Stations located 432 earthquakes in Utah. Earthquakes magnitude 3.0 or larger are plotted as stars. Three earthquakes were reported felt during this period. Magnitude indicated here is either local magnitude, M_L, or coda magnitude, M_C. All times are Mountain Daylight Time.

• Eastern Wasatch Plateau-Book Cliffs area near Price (coal-mining related): Five clusters of seismic events (magnitude 0.9 to 3.3) make up 56% of the shocks that occurred in Utah. These clusters are located: (a) 20 miles E of Price, (b) 25 miles WNW of Price, (c) 20 miles SW of Price, (d) 25 miles SSW of Price, and (e) 35 miles NE of Richfield. Significant shocks:

M_C 3.0	July 27	4:00 a.m., Part of cluster (d)
M_C 3.3	Sept. 27	5:21 a.m., Part of cluster (d)

• Northern Utah: A cluster of eight earthquakes occurred five miles SSW of Malad City, Idaho (30 miles NW of Logan). Most of these earthquakes occurred in late September.

During July and August, a series of 15 earthquakes occurred five miles NW of Park City (15 miles SE of Salt Lake City). The majority of these shocks were less than magnitude 1.0. Seismic activity is sporadic in this area.

Throughout the report period, a series of earthquakes occurred five miles W of Midway (15 miles NE of Provo), in the general vicinity of Deer Creek Reservoir, and ranging in magnitude from 0.2 to 1.6. Seismic activity is sporadic in this area.

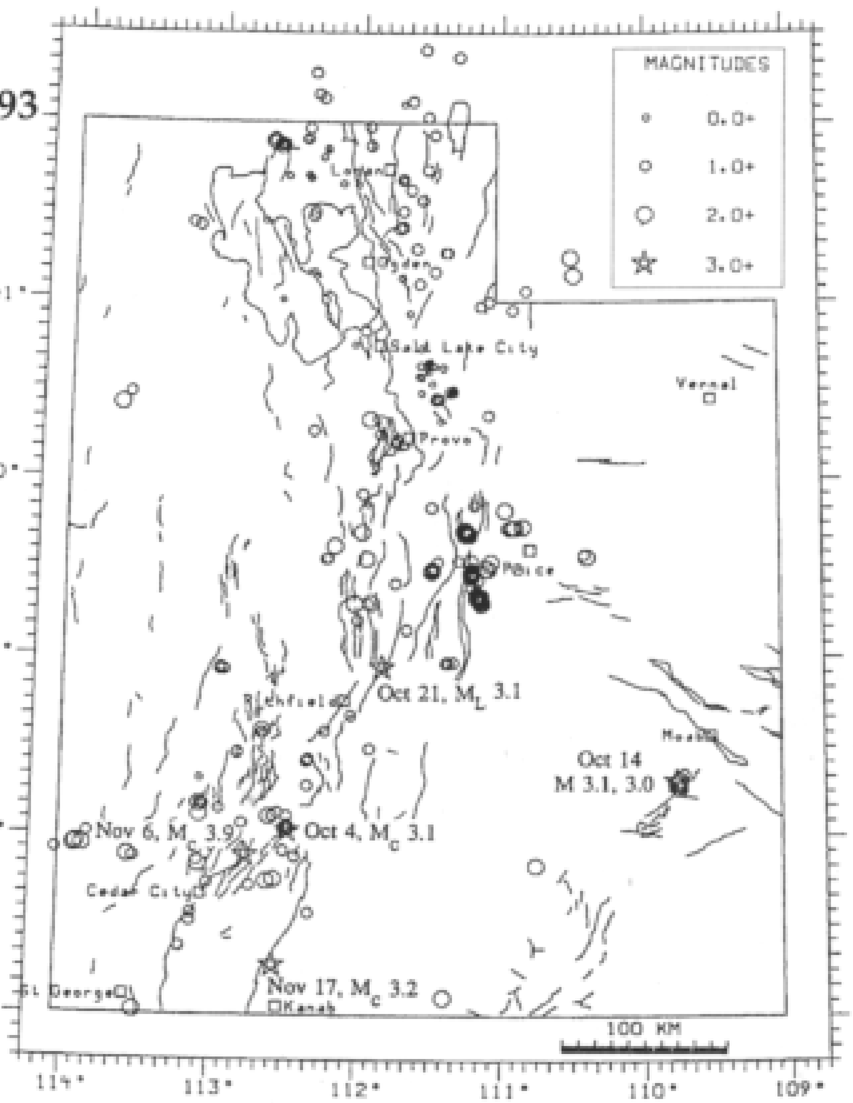
• Southern Utah: A cluster of six earthquakes occurred in late August, five miles S of Summit (five miles E of Cedar City). Earthquakes in this cluster ranged in magnitude from 1.5 to 2.2.

Significant earthquakes:

M_L 3.7	July 2	6:16 p.m.	5 miles SSW of Malad City, ID, felt in Malad City, ID
M_C 3.3	September 23	4:04 p.m.	6 miles S of Malad City, ID, felt in Malad City, ID
M_C 3.1	July 27	9:21 p.m.	39 miles N of Dinosaur, CO
M_L 3.5	July 19	9:57 p.m.	2 miles E of Richfield, felt in Annabella, Aurora, Elsinore, Glenwood, Kanosh, Koosharem, and Richfield
M_C 3.0	August 9	1:25 p.m.	10 miles WNW of Panguitch

Additional information on earthquakes within the Utah region is available from the University of Utah Seismograph Stations.

October 1 - December 31, 1993



During October 1 through December 31, 1993, the University of Utah Seismograph Stations located 389 earthquakes within the Utah region. The total includes six earthquakes in the magnitude 3 range and 163 in the magnitude 2 range. Earthquakes which have magnitudes of 3.0 or larger are plotted as stars and specifically labeled on the epicenter map. There was only one earthquake reported felt during the report period. Magnitude is either local magnitude, M_L, or coda magnitude, M_C. Mountain Daylight Time is used through October 30, Mountain Standard Time for the remainder.

• Eastern Wasatch Plateau-Book Cliffs area near Price (coal-mining related): Three clusters of seismic events (magnitude 0.9 to 3.3) make up 42% of the shocks that occurred in Utah during the report period. These clusters are located: (a) 25 miles WNW of Price, (b) 25 miles WSW of Price, (c) 30 miles SW of Price.

• Northern Utah: A cluster of 15 earthquakes occurred 25 miles W of Garland (40 miles WNW of Logan). Most of the earthquakes in this series occurred from December 6th through December 8th.

Throughout the report period, two clusters of earthquakes occurred in the Heber City area (30 miles SE of Salt Lake City). The clusters are located: (1) 4 miles SSE of Midway, and (2) 4 miles E of Heber City. The majority of the shocks were less than magnitude 1.0. Seismic activity is sporadic in this area.

• Central Utah: A series of 19 earthquakes occurred 1 mile NE of Spring City (40 miles WSW of Price). The shocks ranged in magnitude from 1.2 to 2.8. Significant earthquakes include:

M_L 3.1	October 21	4:07 p.m.	2 miles ESE of Salina, felt in Salina and Redmond.

• Southern Utah: A cluster of eight earthquakes occurred 22 miles SW of Moab, in a remote area located west of Canyonlands National Park. The shocks ranged in magnitude from 1.2 to 3.1.

A series of ten earthquakes occurred during October, 13 miles SW of Circleville (40 miles NE of Cedar City). Significant earthquakes include:

M_C 3.1	October 4	8:24 p.m.	14 miles NNW of Panguitch
M_C 3.0	October 14	9:57 a.m.	23 miles SSW of Moab
M_L 3.1	October 14	12:39 p.m.	22 miles SSW of Moab
M_L 3.5	November 6	12:30 a.m.	5 miles NE of Parowan
M_C 3.2	November 17	3:48 a.m.	4 miles E of Orderville

"Glad You Asked"

by Rebecca Hylland

"Glad You Asked" is a new column to appear regularly in Survey Notes. In each issue, Rebecca Hylland of the Geologic Extension Service will answer a geologic question commonly asked by the public.

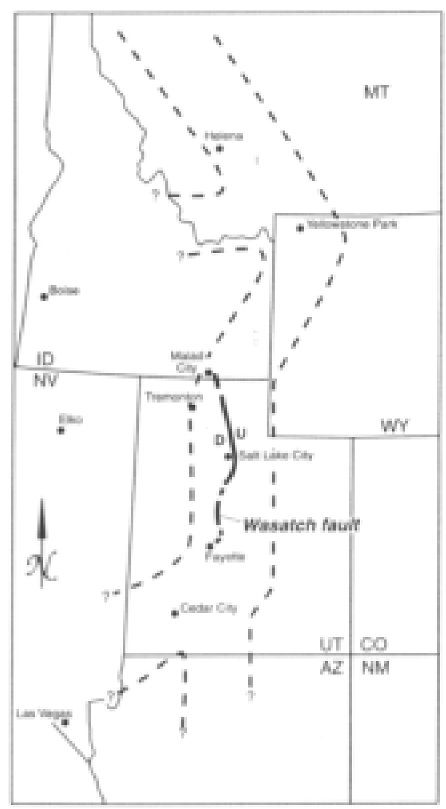
Recent earthquake activity has prompted several Utah residents to inquire about the similarities and differences between the Wasatch fault in Utah and the San Andreas fault in California.

Differences between the two faults are great: they differ in their structure and in the forces driving their movement. The Wasatch fault is a *normal* fault located in the interior of a plate, and the San Andreas fault is a *strike-slip* fault located at a plate boundary.

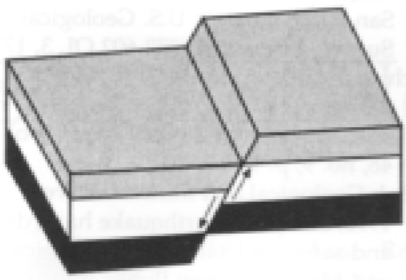
The earth's crust has several plates that are less dense than the molten layer that underlies them. This density difference allows the plates to float and move with the mantle's currents. Plate boundaries are where plates meet, and are zones of increased seismic (earthquake) and volcanic activity. The study of plate movement is called *plate tectonics.*

Faults are zones along which rocks break; rocks on one side of the fault move either horizontally or vertically in an opposite direction relative to rocks on the other side. Faults are found along plate boundaries as well as within a plate's interior. When the rocks break along faults, the energy released is an earthquake.

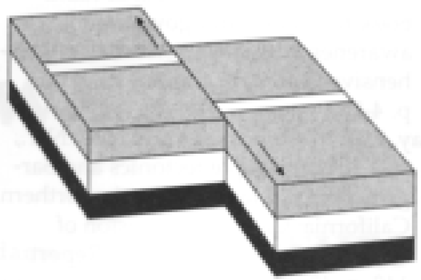
Three of the physiographic provinces of the western United States, the Wasatch and San Andreas faults, and tectonic plate boundaries. "D" indicates the down-dropped (valley side) of the Wasatch fault. The "U" indicates the up-thrown (mountain side) of the Wasatch fault. The arrows show relative direction of plate movement. (modified from U.S. Geological Survey's United States physiographic divisions and provinces map, 1962)



The Intermountain seismic belt (zone between dashed lines) and approximate location of the Wasatch fault. "D" denotes the down-dropped side of the Wasatch fault. "U" identifies the up-thrown side of the Wasatch fault.



Block diagram of a normal fault.



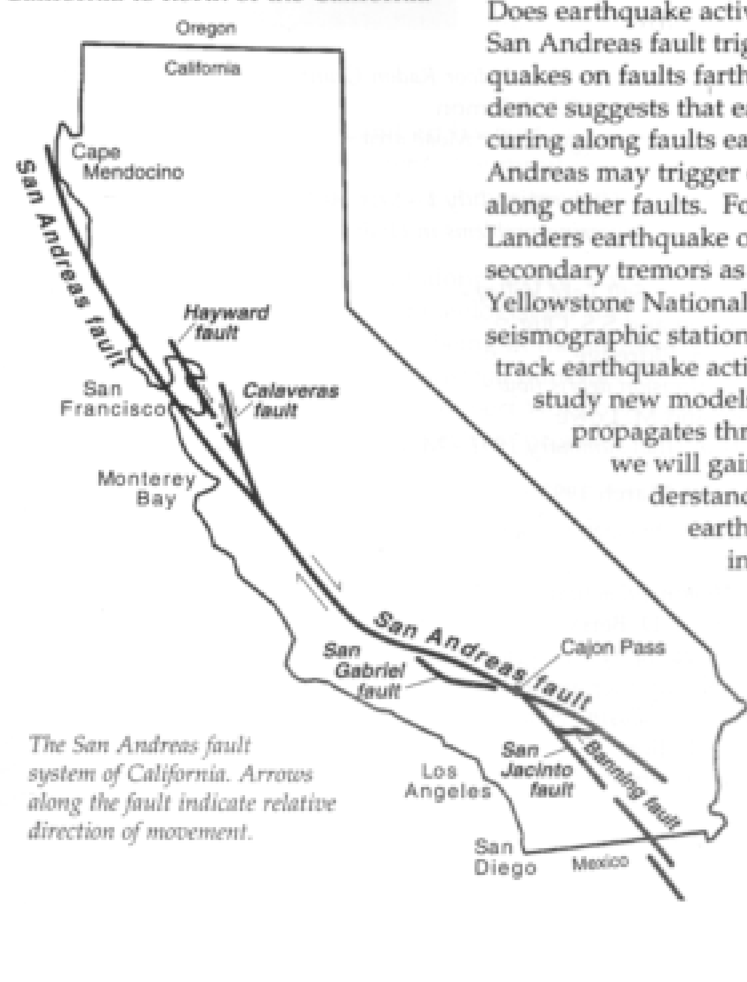
Block diagram of a strike-slip fault.

The Wasatch fault is located within the interior of the North American plate in the Intermountain seismic belt (ISB), a zone of pronounced earthquake activity. The ISB is about 120 miles wide and extends 800 miles in a north-south direction, from western Montana to northern Arizona. The ISB trends through the center of Utah and encompasses the boundary between the Basin and Range Province to the west and the Middle Rocky Mountains and Colorado Plateau Provinces to the east.

The crust in the Basin and Range Province is relatively thin, ranging between 15 and 18 miles thick, and is being stretched in an east-west direction. Stress associated with stretching eventually causes the crust to rupture along faults. Repeated faulting created many of the north-south- trending valleys and mountains between the Wasatch Range in Utah and the Sierra-Nevada Mountains in California. The Basin and Range mountains are *fault blocks* that during earthquakes, up-lift and rotate while the valleys drop down. Faults bounding these blocks are *normal* faults because movement along them is in a vertical direction.

The Wasatch fault is a zone of normal faults and is composed of about 10 discrete segments that rupture independently of one another during earthquakes. The average time between large (magnitude 7.0-7.5) earthquakes along the fault between Brigham City and Nephi is about 400 years. The Wasatch fault zone is the longest (over 200 miles) and most active normal fault in the United States.

The San Andreas fault forms the boundary between the North American and Pacific plates and is part of a complex system of parallel and branching faults. The San Andreas fault is a name applied to the main, most recent surface expression of rupture within the San Andreas fault system. Other faults within the system include the Hayward, Calaveras, San Gabriel, San Jacinto, and Banning. The San Andreas fault extends from Cape Mendocino in northern California to north of the California-Mexico border. The San Andreas fault system is more than 800 miles long and 6 miles wide. Faults in the San Andreas system are *strike-slip*, in which movement along them is horizontal; the Pacific plate is moving in a lateral, northwesterly direction relative to the North American plate. The San Andreas fault system is the largest and most active strike-slip fault in the United States.



The San Andreas fault system of California. Arrows along the fault indicate relative direction of movement.

Like the Wasatch fault, the San Andreas fault is divided into 10 segments that move independently during earthquakes. The southern segments, from Monterey Bay south, produce large earthquakes about every 150 years. Segments north of Monterey Bay produce large earthquakes about every 100 years. The difference in recurrence intervals is not yet fully understood.

Can we expect a large earthquake to occur along either fault? We can. The largest earthquake expected for the Wasatch fault is a magnitude 7.5, and magnitude 8.5 or greater is expected along the San Andreas fault. Does earthquake activity along the San Andreas fault trigger earthquakes on faults farther inland? Evidence suggests that earthquakes occuring along faults east of the San Andreas may trigger earthquakes along other faults. For example, the Landers earthquake of 1992 triggered secondary tremors as far away as Yellowstone National Park. As more seismographic stations are placed to track earthquake activity and as we study new models of how energy propagates through the earth, we will gain a better understanding of how earthquake events interrelate.

continued. . .

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Survey Notes Index

Survey News

In early June, **Roy Adams** started work in the Economic Geology group at the Utah Geological Survey working on the Ferron Project funded by the Department of Energy. He recently completed a Doctorate in Geological Sciences at the Massachusetts Institute of Technology (MIT). His dissertation investigated cyclicity and sequence stratigraphy in Cambrian-age carbonate and siliciclastic deposits in southeast California and southwest Nevada. Prior to attending MIT, Roy worked in the petroleum industry as a consultant and for Exxon as a research geologist and explorationist. He also has a M.A. in geology from Rice University and a B.S. in geology from the University of California at Riverside.

Francis Ashland received his B.S. in Engineering Geology from Purdue University in 1984, his M.S. in Geology from the University of Massachusetts in 1993, and is currently finishing work towards a Ph.D. in Geological Engineering from the Colorado School of Mines. Frank was the Association of Engineering Geologist's 1993 Marliave Scholar. He has just begun, as part of the Utah Geological Applied Geology Program, a study of the Park City area, with emphasis on the relationship of geology to ground-water conditions. Frank was with Goldberg-Zoino & Associates in Massachusetts from 1985 to 1990 where he performed geologic studies for geotechnical and environmental projects, including slope-stability analysis, bedrock mapping for rock excavations, and regional mapping for tunnels.

DOE Grant Received

DOE announced that the ESRI-UGS-ARCO team Class III reservoir proposal was selected for funding. The project will work on slope-basin sediments in the Midway-Sunset oil field in California. UGS is being funded 100% (no cost share from us). This enhances our growing reputation as a regional center in geoscience research. Doug Sprinkel will be UGS's principal investigator on the project.

NEHRP Grant

The Applied Geology program has received a grant from U.S. Geological Survey through their National Earthquake Hazards Reduction Program (NEHRP). Surficial geology on the west side of Cache Valley is to be mapped at a scale of 1:24,000. The goal is to identify paleoseismic history of the Cache Valley fault zone. The next phase would be to determine where to dig a trench to verify past movement and to constrain the timing of past seismic events.

Rebecca Hylland is the new geologic technician with the Geologic Extension Service (GES). She received her bachelor's degree in geology from Western Washington University. Rebecca has 4 years experience working as an engineering and environmental geologist for a geotechnical consulting firm in the Seattle area.

Lynda Lambert has just joined us as the new receptionist. A resident of Summit Park, she has lived in Utah all her life. Lynda comes to us from the State Treasurer's office.

Moving right along, **Bryce Tripp** has accepted the position of Senior Geologist for the UGS Economic Geology Section. After being in the section fifteen years and specializing in industrial minerals for the last several years, he will replace Robert W. Gloyn who has become Staff Scientist for economic projects.

Another move, from the Economic Section to the Applied Section, involved **Charles Bishop**. Charlie worked on many projects while in Econ, most recently specializing in tar sands studies, and is trying his hand at hydrologic studies in Snyderville basin.

Vajdieh Marxen left for Mankato, Minnesota. She has been an integral part of our computer resource group for five years and will be sorely missed.

LaDonna Henderson, our receptionist for the last two years, has gone to work for the Department of Human Services, Office of Recovery Service. We hope she recovers!

Fault study continues in Sandy's east bench

The Utah Geological Survey (UGS) is currently conducting a fault-trenching project on the Wasatch fault zone in Sandy, Salt Lake County. Co-sponsored by the U.S. Geological Survey's National Earthquake Hazard Reduction Program (NEHRP), the purpose of the study is to construct a complete chronology of surface-faulting earthquakes for the Salt Lake City segment of the Wasatch fault during at least the past 6,000 years. UGS Deputy Director Bill Lund, and UGS Applied Program geologist Bill Black are the principal investigators for the project. The current work will build on that begun nearly a decade ago, when the UGS became involved in a paleoseismic study of the Wasatch fault. The UGS is re-trenching the Salt Lake City segment in part ". . . to take advantage of improved logging and radiocarbon dating techniques that were not available for the original study in 1985," says Black.

Deputy Director Bill Lund discusses the trenching project with a member of the local media. (photo by Bill Black)

Five trenches were excavated across fault scarps during the summer of 1994. Logging of the trenches is nearly completed, and soil samples have been sent to labs for radiocarbon dating. Field trips to the trench sites are planned for autumn; the trenches will be back-filled shortly thereafter. Results of the study should be available in the spring or early summer of 1995.

NEW PRODUCT

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Utah Geological Survey • 2363 South Foothill Drive • Salt Lake City, UT 84109 • (801) 467-0401

New Publications of the UGS

Map Series

Utah geological highway map, by L.F. Hintze, 1975, 1:1,000,000, 37" x 24" BYU-3. .... **$5.00**
This is an old standard, extremely useful to geologist and layman alike while travelling Utah's roads.

Geologic map of the Harley Dome quadrangle, Grand County, Utah, by G.C. Willis, 18 p., 2 pl., 1:24,000, 1994 M-157 .... **$6.00**

Geologic map of the Sunset Pass quadrangle, Box Elder County, Utah, by D.M. Miller and J.D Schneyer, 14 p., 2 pl., 1:24,000, 1994 M-154 .... **$6.00**

Geologic map of the Gold Bar Canyon quadrangle, Grand County, Utah, by H.H. Doelling, W.A. Yonkee and J.S. Hand, 26 p., 2 pl., 1:24,000, 1994 M-155 **$6.00**

Special Study Series

The quartzite building stone industry of the Raft River and Grouse Creek Mountains, Box Elder County, Utah, by B.T. Tripp, 19 p., 1994, SS-84 .... **$5.00**
A definitive examination of the existing quarries and stone available, it serves as a good companion to the *Utah Stone* brochure, also by Bryce, which provided a colorful depiction of the architechtural stone of Utah (see PI-17 in our Publications List).

Seismotectonics of north-central Utah and southwestern Wyoming, by M.W. West, 93 p., 5 pl., 1:100,000, 1994. This is the fourth in the series *Paleoseismology of Utah*, an ongoing set of reports examining seismotectonics in Utah. **$15.00**

Radon-hazard-potential areas in Sandy, Salt Lake County and Provo, Utah County, Utah by B.J. Solomon, B.D. Black, D.L. Nielson, D.L. Finerfrock, J.D. Hulquist, and Cui Linpei, 49 p., 1994 SS-85 .... **$ 6.00**

Public Information Series

Oil and gas pipeline map of Utah, compiled by T.C. Chidsey Jr. and P.B. Anderson, 1 color pl., 1:1,000,000, 5/1994, PI-22 .... **$5.00**
Still the only recent update to the pipelines in Utah, this map gives an overview of distribution and gathering networks.

Rules and regulations regarding rock and mineral collecting in Utah, by GES staff, 1 p., 6/1994 PI-23...**FREE**

Special issue on Utah (reprint of *Rocks & Minerals* Utah Special) 62 p., 1994 PI-26 .... **$3.50**
A very interesting collection of articles focused on Utah's minerals and mining history. Included are: a short geologic history of Utah, an overview of mineral collecting in Utah, articles on the Big Indian copper mine, the Park City District, the Repete mine, the Centennial Eureka mine, and Bingham. A short piece by the Gunthers has two pages of great trilobite drawings.

Oper-File Report

Exploring for new oil in old fields, Salt Wash Field: a case study, by C.D. Morgan, 41 p., 2 pl., 3 diskettes, OFR-307 .... **$25.00**

Earthquake potential evaluation of the Oquirrh fault zone, central Wasatch Front, Utah by S.S. Olig, W.R. Lund, B.D. Black, and Bea Mayes, 46 p., 18 figs., 1 pl., August 1994 OFR-308 .... **$8.20**

Interim geologic map of the Midvale quadrangle, Salt Lake County, Utah, by F.D. Davis, 45 p., 2 pl., 1:24,000, August 1994 OFR-310 .... **$6.60**

Low-temperature geothermal water in Utah: a compilation of data for thermal wells and springs through 1993, by R.E. Blackett, 74 p., 2 pl., 1:750,000, July 1994 OFR-311 .... **$9.00**

Interim geologic map of the Richfield quadrangle, Sevier County, Utah by G.C. Willis, 105p., 2 pl., 1:24,000, 1/94 OFR-309 .... **$12.00**

Outside Publications

Carboniferous of the northern Rocky Mountains, J.T. Dutro, editor, 1979, 59 p., American Geological Institute Guidebook #3 AGI-3 .... **$2.00**

All the 1:24,000 scale (7.5-minutes) topographic maps of Utah from the U.S. Geological Survey

All the 1:62,500 scale maps still available for Utah (hikers and hunters may remember this older set as being very useful - each one covers the area of four 7.5' maps)

All the 1:100,000 USGS topographic maps of Utah

Many of the geologic maps of Utah from the USGS

Order form on page 29.

Recent Publications of Interest

(Not available from UGS)

From prospect to prosperity, wildcatting in Arabia and the Rockies, by P.T. Walton, 1994, 325 p.: Utah State University Press. An interesting recounting by Paul Walton of his adventures in Utah and Saudi Arabia. He was instrumental in opening the area's oil capabilities, thereby making J. Paul Getty the richest man in the world. But he is known in Utah as the one who discovered the Clear Creek gas field in Carbon County. The background information given in the book, a bit like reading an insider's view of Hollywood, will be of interest to anyone in oil and gas in Utah.

Coal mine bumps as related to geologic features in the northern part of the Sunnyside District, Carbon County, Utah, by F.W. Osterwald, C.R. Dunrud, and D.S. Collins, 1993, 76 p., 5 plates: U.S. Geological Survey B-1514

Structure and stratigraphy of Upper Cretaceous and Paleogene strata (North Horn Formation), eastern San Pitch Mountains, Utah; sedimentation at the front of the Sevier orogenic belt, by T.F. Lawton and others, p. II1-II33, 2 plates: U.S. Geological Survey B-1787-II

Surface vitrinite reflectance study of the Uinta and Piceance basins and adjacent areas, eastern Utah and western Colorado; implications for the development of Laramide basins and uplifts, by R.C. Johnson and V.F. Nuccio, 1993, p. DD1-DD38, 2 plates: U.S. Geological Survey B-1787-DD

Stratigraphy, structure, and paleogeography of Pennsylvanian and Permian rocks, San Juan Basin and adjacent areas, Utah, Colorado, Arizona, and New Mexico, by A.C. Huffman, Jr., and S.M. Condon, 1993, p. 01-044, 18 plates: U.S. Geological Survey B-1808-O

Kinematics of the Aspen Grove landslide, Ephraim Canyon, central Utah, by R.L. Baum, R.W. Fleming, and A.M. Johnson, 1993, p. F1-F34, 1 plate: U.S. Geological Survey B-1842-F

Sedimentologic analysis of cores from the Upper Triassic Chinle Formation and the Lower Permian Cutler Formation, Lisbon Valley, Utah, by R.F. Dubiel and J.L. Brown, 1993, p. E1-E40: U.S. Geological Survey B-2000-E

Heterogeneous Neogene strain and its bearing on horizontal extension and horizontal and vertical contraction at the margin of the extensional orogen, Mormon Mountains area, Nevada and Utah, by R.E. Anderson and T.P. Barnhard, 1993, 43 p., 5 plates: U.S. Geological Survey B-2011

Tertiary calderas and regional extension of the east-central part of the Tintic-Deep Creek mineral belt, eastern Great Basin, Utah, by D.B. Stoeser, 1993: U.S. Geological Survey B-2039A, p. 5-23.

Geologic map of the Horse Flat Quadrangle, Kane County, Utah, by W.E. Bowers, 1993, scale 1:24,000: U.S. Geological Survey C-144 (coal investigations)

Analytical results and sample locality map of stream-sediment and heavy-mineral-concentrate samples from the Deep Creek Mountains Wilderness Study Area, Juab and Tooele counties, Utah, by B.F. Arbogast, P.L. Hageman, R.H. Hill, D.L. Fey and D.R. Zimbelman, 1993, 22 p., 1 pl., scale 1:50,000: U.S. Geological Survey OFR-92-259

Water-resources activities in Utah by the U.S. Geological Survey, October 1, 1990 to September 30, 1991, by J.S. Gates and E.E. Hardy, 1992, 49 p.: U.S. Geological Survey OFR-92-497

Selected hydrologic data for Salt Lake Valley, Utah, 1990-92, with emphasis on data from the shallow unconfined aquifer and confining layers, by S.A. Thiros. 1992, 60 p., 1 pl.: U.S. Geological Survey OFR-92-640

Preliminary geologic map of the Parowan Quadrangle, Iron County, Utah, by Florian Maldonado and R.C. Moore, 1993, 11 p., 1 pl. scale 1:24,000: U.S. Geological Survey OFR-93-3

Preliminary geologic map of the Enterprise Quadrangle, Washington and Iron counties, Utah, by H.R. Blank, 1993, 33 p., 1 pl. scale 1:24,000: U.S. Geological Survey OFR-93-203

Annotated bibliography of metallogenic maps (material mostly published between 1960 and 1987), compiled by M.P. Foose and K. Bryant, 1993, 91 p.: U.S. Geological Survey OFR-93-208A&B

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Meetings and calls for papers

American Geophysical Union fall meeting is in San Francisco, California, on December 5-9, 1994. Contact AGU Meetings, 2000 Florida Ave. N.W., Washington, DC 20009, (202) 462-6900.

Call for papers on the Environmental and Engineering Geology of the Wasatch Front Region. The **Utah Geological Association** 1995 field conference will be edited by William R. Lund. Title and 250-word abstract are due by December 16, manuscripts due March 15, 1995. Contact W.R. Lund, Utah Geological Survey, 2363 S. Foothill Drive, Salt Lake City, UT 84109, (801) 467-7970, fax (801) 467-4070.

Society for Mining, Metallurgy, and Exploration annual meeting, March 6-9, 1995 in the Colorado Convention Center, Denver, Colorado: Meeting the Global Challenge. Contact Meetings Dept. SME, P.O. Box 625002, Littleton, CO 80162-5002, (303) 973-9550.

Call for papers by the **Rocky Mountain Section of GSA**. Abstracts are due January 20, 1995 for the meeting May 18-19 in Bozeman, Montana. Contact David R. Lageson, Department of Earth Sciences, Montana State University, Bozeman, MT 59717-0348, (406) 994-6913.

Geological Society of America annual meeting is November 6-9, 1995 in New Orleans, Louisiana. Abstract deadline is July 12, 1995.

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